

The Art & Skill of Radio-Telegraphy

-Second Revised Edition-
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Chapter 29 - The Koch Researches

The obviously extensive researches of Ludwig Koch, psychologist at Die technische Hochschule, Braunschweig, Germany, reported in Jan-Feb. 1936 (see [Sources](#)), seem to be virtually unknown outside of Germany. His goal was to discover the most efficient way to teach the Morse code to prospective radiotelegraph operators to meet the International requirements for commercial radio operators. These requirements were:

- send 100 words in five minutes,
- copy a 100 word telegram in five minutes, and
- copy 125 words of ordinary text in five minutes, one word being reckoned as five letters

Koch's researches involved: determining what competent operators are doing, examining teaching methods in current use, then devising better methods, and testing them in actual classes. His conclusions and recommendations seem to be the earliest real research into how best to teach the Morse code. They agree on the whole with the best methods of today, and may offer some further ideas of value to us. They are summarized [here](#).

TESTS TO DETERMINE WHAT COMPETENT OPERATORS ARE DOING

He ran three series of tests to determine how the code is comprehended and for this purpose used four competent, actively-practicing radio telegraphers. Three of these operators had learned the code solely by sound, while the fourth was self-taught from printed code charts.

SENDING TESTS

For the first test each operator was to send by regular handkey the series of ten letters b c v q f l h y z x at various speeds while monitoring his sending with a pair of headphones to satisfy himself as to its quality. Out of his sight and hearing a recording system made an accurate timed graphical record of his sending, so that the actual timing of signal and space durations could be examined in detail. He was instructed to send, using standard International Morse timing, at each of six different speeds ranging from about 20 to 80 characters per minute. Standard International Morse timing, as described in [Chapter 12](#), was then used to compare their sending at all speeds.

Below about 10 wpm the only operator who closely conformed to standard timing was the one who had visually learned the code. The three others deviated considerably from "standard" timing. At 5 wpm these deviations were appreciable:

- the dits were too short,
- the dahs tended to be longer than 3 times dit length, and
- the spaces between characters were too long.

However, spacing between the components of a letter was almost perfectly equal to their dit lengths.

At successively higher speeds this situation changed slowly and somewhat irregularly until by about 10 wpm character rate all four operators were forming fairly accurate patterns of sound (nearly to the International Standard), except that the letters themselves were somewhat faster and the spaces between letters were somewhat longer than standard. By about 12 wpm all sending had become quite consistent with the standard. (Only the well-known individual peculiarities of sending by hand were obvious. At 10 wpm and above these deviations were always very small.)

The three operators who had learned by sound obviously showed no real sense of sound patterning (Gestalt) at these very low speeds: no sense of unity, but rather just a series of separate elements strung together. Only by about 10 wpm were the code characters now felt to be entities of sound in themselves, patterns which were clear-cut in each operator's mind, no longer shattered elements, disjointed parts.

RECEIVING TESTS

Test number One: - Each operator was to copy the 30 German Morse characters sent by a machine in perfect "standard" timing at each of four different speeds over the same speed range as before.

At about 5 wpm these experienced operators hardly recognized a single character correctly! At 7 wpm only 40% to 60% of the letters were correctly identified. At 10 wpm all operators were getting about 95% correct. By 12 wpm all of them correctly identified every character.

Test number Two: - Here the length of the spaces between the letters was doubled. This time the operators recognized almost all letters correctly at all speeds. That is interesting.

From these tests it was concluded that experienced operators recognize a code character by its overall acoustic pattern (Gestalt), and that this pattern stands out clearly only when sent at a minimum character speed of about 50 characters per minute. At lower speeds it is heard simply as a disjointed series of signals. -- Koch concluded that these operators could recognize the too-slowly sent letters only when letter spacing was doubled, because this increased interval gave them time to integrate the sound and mentally speed it up to where they could recognize it. (A beginner would not have the skill to do this.)

The operator who had learned from a printed code chart apparently formed better proportioned characters at very low speeds because his visual mental picture was so strong. However, the price paid for this was that it limited his maximum speed of copying: he could barely meet the minimum requirements - a marginal operator. (See below.)

ANALYSIS AND CRITICISM OF PREVIOUS TEACHING METHODS

The "Analytic" Method introduces the student to the code using some sort of systematic arrangement, or chart, where the code characters are arranged by number and type of related elements, etc., in a visual form. The student is required to memorize this as a mental picture before going any further. After that, the characters are sent to him in standard timing, at first very, very slowly. This means they are sent with long drawn out dits, dahs and spaces. The speed is then very gradually increased in tiny steps.

The faults with this system are:

- To begin by learning visual symbols creates a useless detour
- Slow sending destroys any unity, or coherent sound-patterning
- The disjointed signal doesn't meet our need for a sense of unity
- Learner can hardly help counting the dits and dahs
- the long spaces between letters distract his attention from listening by:

- encouraging him to think and try to put the shattered parts together to make sense of them, a shaped unity, (Gestalt), or
- guessing what may come next
- at each increase in speed everything sounds different, and he virtually has to start over again.

In short, the student is sidetracked and severely penalized all the way along: needlessly translating from bits and pieces of sound to try to put it together into a meaningful whole, then converting that to visual form and then finally to the letter.

The "Sound-Pattern" Method first introduces the Morse characters to the student at a character speed fast enough for them to be perceived as an acoustic unity (Gestalt), but with wide spaces between the characters. However, the student has usually already visually mastered a code table or is encouraged to do so as he learns.

Unfortunately, visual mental pictures are usually very much stronger and easier to recall than auditory sound patterns. Thus the student tends to convert the signal pattern he hears into the corresponding visual representation, break it into its component parts, and then finally into the letter. This complex action tends at least partially destroys the wholeness of the acoustic impression.

This series of actions is encouraged by the long pauses between characters, giving adequate time for thinking, speculation and the cumbersome translation processes. With increasing speeds the pause time becomes too short to go through all this, and so the student gets stuck below or around 10 wpm, just as with the analytic method.

So this method tends to suffer about the same faults as the analytical method. Both generally lead directly to that troublesome plateau at around 10 wpm, where the distinct change in perception from bits and pieces to coherent unity of each signal occurs.

Analyzing these methods, two classes of errors can be seen:

- Errors which hinder the building of a sense of acoustic unity
 - Detour through an optical symbol.
 - Disintegration of the acoustic form of the character.
- Errors which prevent going directly from acoustic impression to the letter:
 - Thinking about the signal during long pauses.
 - Guessing what may come next.
 - Converting or translating from sound to visual and from visual to the letter
 - Converting or integrating into a total rhythm pattern.

The remedy is obviously to eliminate all visual references and associate the sound directly with the letter, to send fast enough from the very beginning so that coherent sound patterns are immediately sensed, and to eliminate non-normal spacing between letters.

TESTS TO ESTABLISH A BETTER TEACHING METHOD

CHARACTER SPEED FOR INITIAL LEARNING ?

The obvious goal was to meet the International requirements. The question is how best to get there. Would it be better to begin from the first using a 100 character rate per minute, or some lesser speed? This experiment was tried. For the average student it was found that the demands on his concentration were significantly greater at 100 letters per minute than at 12 letters per minute, especially as more and more new characters were introduced. (Above average students did well, however, at the higher initial speed.) But, of

course, if one learns initially at some lower speed, speed is going to have to be increased to meet the requirements.

Various tests showed that about 12 wpm was an optimal speed for most people to begin learning. It is far enough above the 10 wpm plateau to avoid it. Further tests showed that once the student had mastered all the code characters at 12 wpm, it was relatively easy for him to advance to 70 letters per minute, and by continuing to practice using the same principles, to advance fairly rapidly, step by step, to the required speeds. Thus a 12 wpm beginning speed seemed well justified.

CAN THE RHYTHM PATTERNS BE ENHANCED ?

Koch observed that in the early stages of learning, the beginner has to concentrate intensely to catch the letter rhythm-patterns. Is there anything which could be done make this easier for him?

He observed that some teachers were speaking, or even almost singing, the sound patterns of code characters using the syllables "dit" and "dah", whose vowel qualities and lengths make sound patterns stand out somewhat like little melodies. This helps accentuate the differences between sound patterns and simultaneously promotes an immediate sense of meaningful unity of the acoustic patterns.

Could the use of two different pitches, one for dits and the other for dahs, make it easier for the new student to recognize the wholeness of the rhythmic pattern ("melody") of a code character, and make it easier to learn? Could it help reduce the stress caused by the intensity of his concentration in the early learning stages, while he is being introduced to the rhythms and trying to get accustomed to them? It looked worth a try.

He conducted two classes simultaneously to evaluate the merits of the two-tone approach. After the first lesson, at each stage the two-tone group averaged two lesson periods ahead of the monotone group. (For the two-tone class the pitches were gradually merged into one by about mid-course.) Results:- the two-tone class in 24 sessions reached what took the monotone class 28 lessons to achieve. Total teaching time was 12 (two-tone) to 14 (monotone) hours. (With both groups there were the usual, occasional short plateaus, each lasting generally no more than one lesson period.) Conclusion: - this is a worthwhile improvement to help the beginner.

WHAT LETTERS SHOULD BE TAUGHT FIRST ?

1) Distinguishing Between Similar-Sounding Patterns.

What characters should first be presented to the student? Although tests had shown that students can, in their first lesson, readily learn to distinguish similar patterns such as the series e-i-s-h, the degree of concentration required had a negative effect on them. Experience has shown that many sound patterns, as speeds rise, can be mistaken for similar sounding patterns, especially in regard to the number of dits which become pretty short at higher speeds: e.g., S and H, or U and V. The dah characters do not run this risk so much: e.g., W and J. In addition some beginners do experience temporary confusion between mirror image characters, such as B and V, D and U. Thus it seems best to begin with sound patterns which are distinctly and obviously different. In this way the student can learn more gradually to discriminate between smaller differences.

2) Letters that Tend to be Troublesome

Koch says these (for German students) are generally x y p q. (Z is very frequent in German.) If these are introduced during the first third of the program, there is more opportunity to give them adequate practice, and this generally results in shortening the total program.

WHEN TO INTRODUCE A NEW CHARACTER

His tests showed that it is safe to introduce a new character into the list only after the student knows thoroughly all the characters he has already studied. He set his working standard at a minimum of 90%: that is, not to introduce a new character until the students were getting at least 90% correct copy at any stage. This provided a good measure for comparison, and at the same time let the student evaluate his own progress. It is indeed interesting that the test classes showed that students learned new characters almost in exact proportion to the number of lesson periods (total hours). The experiments also showed that three to four new characters were about optimum for any one lesson period.

SHOULD PRACTICE BE BY GROUPS OF LETTERS ?

The question he asked is this: should the student practice one group of characters until he knows them well, then work on a second group separately in the same way, and after that combine the groups?

He began this teaching test with characters composed of dachs only: t m o ch (German single character ch). After enough practice (a couple of class sessions) to "master" this group of letters, he began teaching the dit group e i s h by itself in the same way. Next he combined these two groups together, and found that somehow during the intensive study of the second group, the students had forgotten the first group almost completely, and their confidence was badly shaken. He had to begin all over again teaching these eight letters together until they were mastered together.

After this, when these eight letters had been practiced to the point where they were correctly and consistently identified, two new groups were studied separately in the same way as the first two groups. First the group d b g, then after that the group u v w. Next, when these two new groups were mixed together, it was found that the d b g group had been forgotten. But worse, after these two groups had been re-learned together (d b g u v w) to the point of correct identification, and then combined with the first 8 letters, alas, the (combined) first two groups of 8 letters had been virtually forgotten!

It appears that the student's intense concentration upon a new group of characters by itself causes that group to override and replace what had been previously "learned". He sensibly concluded that teaching by groups is wrong-headed. Therefore, the most efficient way is to introduce one new letter at a time and then immediately integrate it into the group of letters already learned, until finally the whole alphabet is complete. In this way all the previously learned characters are under constant review and repeated frequently without lapses.

TROUBLESOME CHARACTERS

Experience has shown that quite a few students have some trouble identifying one or more individual characters, tending to miss or confuse them. They show up as little plateaus on his record of advancement. What letters these are varies greatly from student to student. The five-column copying forms described below serve to help identify which these troublesome ones are -- needing more practice.

HOW LONG SHOULD LESSONS BE AND HOW DISTRIBUTED IN TIME ?

He cited B. Jost's researches which found that people learn more quickly and retain it longer for a given total learning time, when the lesson periods are shorter and widely separated in time. E.g., for a total of 24 lesson periods (which always include reviews):- to schedule four lesson periods a day for six days is four times more effective than to schedule eight lesson periods a day for 3 days, and that to schedule two lesson periods a day for 12 days is eight times more effective. That is, spread out the lessons in time.

What is the ideal length of a lesson period? — Koch found by testing that to have a long morning lesson, and then after corresponding length of rest period to continue in the afternoon, demanded too much intense concentration. The students got tired too quickly and the repetition practice was not as effective as it should be. By trial he determined that a half-hour lesson period was about optimum. (Even a 45 minute period began to show diminishing returns.) He finally recommended two half-hour periods, one in morning and one in the afternoon as optimum.

Several courses using various of these principles were conducted. However, at the time of this report, he had not had classes where he could combine all the optimum test conditions. The students savable were people who were interested, but not primarily, at least, for professional purposes. Furthermore, they were employed at full-time work during the day, and were often tired by class time, which had to be scheduled in the evenings. Also, he could schedule only two or three half-hour lesson periods per week. Hardly ideal.

In spite of this progress was good, and no difficulties were encountered. Three to five characters were presented and learned in the first half-hour period. He aimed for many repetitions during each lesson, never less than ten repetitions of each character during a given lesson period, even after the entire alphabet had been introduced. Each successive period began with a lively review of what had been learned up to that point.

NEW PHILOSOPHY FOR TEACHING

- It is a mistake to let the student see a code character in any kind of visual form, because a visual impression is so strong that it will almost invariably lead to analyzing it into dits and dahs, and thus shatter its unity.
- Each Morse code character must retain its unitary nature, its acoustic wholeness at all times. This is facilitated by:
 - Sending at a speed of at least 12 wpm (60 letters/minute) from the very first. This will promote the sense of acoustic unity and bypass the discouraging 10 wpm plateau (transition) region completely.
 - Emphasizing the melodic nature of the code patterns initially, like a little tune, by the use one pitch for the dits and a slightly different pitch for the dahs. These pitches are then gradually to be brought closer together so that by about the mid-point of the program they are identical and continue from there on as a single pitch.
- From the very first all practice is to be in five-letter groups, with normal spacing between the letters, as in ciphered texts, but with distinctly longer pauses between groups. This has a dual purpose:
 - to leave no time for conscious thinking or translation between letters, and thus to require direct passage from sound pattern to the letter itself, and
 - so that the student will immediately become used to hearing letters in groupings as in normal communication, and not as isolated letters.

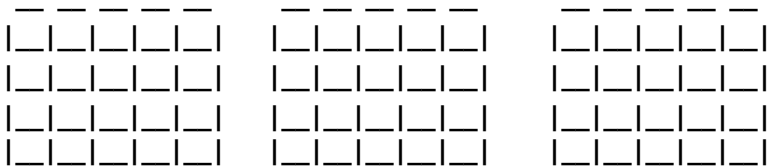
DESIGNING AN EFFICIENT TEACHING PROGRAM

1) The first exercise is to teach the student to hear and begin to become accustomed to hearing the different overall rhythms of sound and silence:-

a) Character rhythm: Character - space - character - space ...

b) Group rhythm: Letter-group - space - Letter-group - space ...

From the very first, to get the student accustomed to overall rhythms, he is supplied with "copying" sheets having several sets of five-column groups of little squares like graph paper, as shown below. They will also be used for all subsequent regular copying practice.



Five letter random groups are then to be sent. At first these will all be unknown letters. As he hears each acoustic pattern of a letter in a five-letter group, he is to place a dot in the square which corresponds to the position of that sound pattern within its group.

Thus he works along across the five-space line, becoming used to hearing each letter-rhythm pattern and then writing a dot for it in the appropriate square. (At this stage he only recognizes the sound patterns as entities, nothing more.) He continues to work line by line down the column as each new group is heard. In this way he begins the practice of focusing:

- a) on the coherent acoustic forms and
- b) on the associated rhythm, letter by letter, of the writing hand, and
- c) on recognizing the pause after each group.

A relatively short initial session (10 minutes or so) of this will begin to accustom him to these overall and detail patterns of sound as entities.

2) The second exercise is to start him on the way

- a) to recognize the differences in rhythm-pattern between two quite different-sounding letters, and
- b) become familiar with the sound patterns of each character, and to become accustomed to them. (All sending to be machine precise.)

A) This begins by introducing the two first characters just as sound patterns - without identifying what letters they are. They are to be sent separately and at random until the student definitely recognizes and distinguishes their individual patterns (pattern one and pattern two, or whatever). At this time they are not yet to be identified with their printed letters: they are simply recognized as different patterns of sound.

B) Only after he has become accustomed to distinguishing the first two letter patterns from each other, and to the rhythm groups as they are, and writing dots in the little squares, is he to be told the names of these first two characters. He should from then on have no difficulty in writing their letters down in the little squares whenever and as he hears them.

This is to train him during these early stages and later on that he is to recognize and react to the presence of each and every acoustic pattern, either by identifying it or by a dot in the square, and of the larger groupings

of letters identified by the longer space.

It is obvious that, especially in the learning stages, there are going to be acoustic patterns passing by which he may or will not be able to recognize immediately and automatically. He must get accustomed to giving such signals no thought at all (except to put down a dot), so that he can give his undistracted attention to the next incoming sound pattern.

Otherwise, during the all-too-short pause after each signal which he does not immediately identify and before the next one is heard, he is going to try to think about what signal it was. But while he is thinking about it the next signal arrives, tending to upset him and cause him to lose the flow of the rhythm. This interruption must from the very first be stopped. His teacher must insist that whenever the student does not immediately and automatically recognize a sound pattern, just to put a dot in the corresponding square, then immediately let it go, and continue on with the rhythm. This action must become habitual, and this technique has been devised to develop it from the very first.

Now as he identifies the acoustic patterns he will write their corresponding letters in the little squares. If the teacher chooses to mix into the 5-letter groups code characters which the student has not been taught, there should be dots to correspond with them.

After one or two short (about 10 min.) practice periods this way, the relationships between the acoustic impression and the letters they represent should have become so closely knit together that there is an immediate transition from the acoustic sound pattern to the letter (or a dot). Only when this point is reached is a third letter to be added to the first two.

3) Only one new letter at a time is to be introduced and added to those already known. The criterion for adding a new letter is: when at least 90% of the letters already well known are correctly identified. Each new letter is added to the group of recognized sound patterns in the same way as the first two were: first by simple recognition of the pattern without knowing what letter it is, and in contrast with the previously known ones, and only when he readily recognizes its individual sound pattern is he to be told what letter it is.

As an example of the introduction of characters and the five-letter groups used, if the sequence of letters taught were h - f - a - g - etc.: for the initial two-character lesson, groups were like:

1. hfhfhf fhfhfh
2. Next character: aahfh fhfhf ...
3. Next: ggba f ghfah ...
4. Next: ccgaf gcafh ..., etc. (In this example he did not begin with the more frequently "troublesome" letters.)

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This page last updated August 02, 1998

Modifications and compile by Thom LaCosta - K3HRN - December 2004